

ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 7

METER ASSEMBLY AND MEASUREMENT OF D.C.

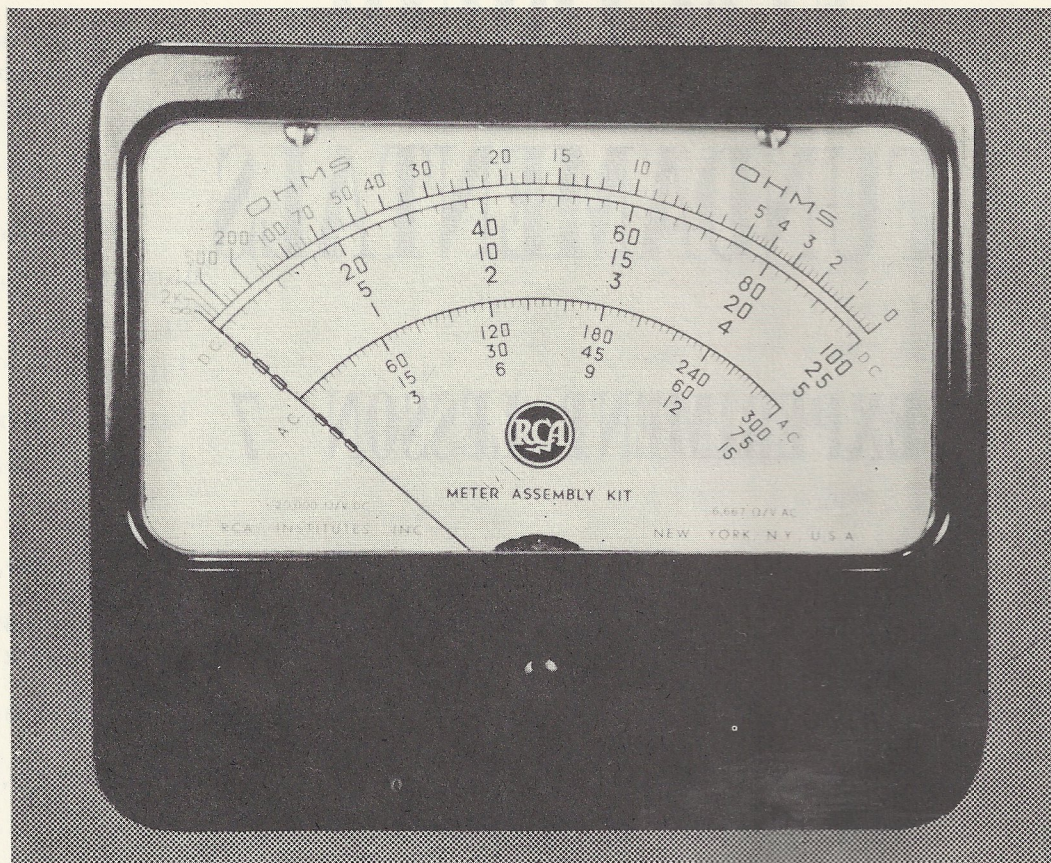


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HOME STUDY SCHOOL

350 West 4th Street, New York 14, N. Y.



All the parts in Kit 4 are listed below. Check the parts you receive against this list. Make sure you have the correct quantity of every item. If a part is either missing or defective upon arrival, request a replacement from Department R, Home Study School, RCA Institutes, Inc., 350 West 4th Street, New York 14, N.Y. Your request must include your name and student number, the complete name and description of the part copied from the Item column below, the Quantity missing or defective, and the reason you are asking for a new part.

KIT 4 BILL OF MATERIALS

Quantity	Item	Quantity	Item
1	50- μ a meter	4	#6 lock washers
4	#6 nuts	2	1/4" brass flat washers
2	1/4" solder lugs, locking type	4	Brass nuts

The fine wire attached to both terminals of your 50- μ a meter movement serves to dampen needle movement during shipment. Remove this wire before performing any experiments and attaching your meter movement to the multimeter assembly. If you ship a movement that has been removed from a multimeter, attach a similar piece of wire across both terminals. If you ship a complete multimeter, it is not necessary to use this wire if you set the FUNCTION switch to DC and the RANGE switch to the 1A position. A meter movement is like a fine watch. It should *not* be opened and serviced by someone who is not an experienced instrument repairman. Opening or tampering with the movement voids the warranty.

If you should experience difficulty with your meter movement or multimeter assembly, write for information and instructions. *Do not return either of these items without writing first.*

Experiment Lesson 7

OBJECT

1. To complete the wiring of the d-c section of the multimeter.
2. To use the multimeter to measure direct current and voltage.

PREPARATION

Before performing any of the experiments in this lesson, carefully read the instructions given in Service Practices 7, How to Use and Read a Meter. After spending so much time and care in preparing your multimeter, it would be downright silly to risk using it without knowing how to use it properly and how to care for it.

PART ONE

EQUIPMENT NEEDED

- Kit 4
- Soldering iron
- Cloth for keeping soldering tip clean
- Solder
- Long-nose pliers
- Cutting pliers
- Adjustable crescent wrench, or 1/4" and 3/8" open-end or box wrenches
- Fine-blade screwdriver

UNPACKING KIT

Caution: Handle this kit with care. It contains your meter movement, which is as

fine and delicate as a watch movement. Don't drop it or do anything to it that you would not do to a fine watch. Learn to care for your meter and it will help you in your work and help you make money; be careless with your meter and you will lose time in your work and spend money for repairs.

Unpack Kit 4 and check the contents against the Bill of Materials. Then, remove the fine wire wrapped around the terminals of the meter. Place the meter and hardware aside for a while.

PREPARATION

1. Examine carefully the work done up to now on your multimeter. See that each resistor and part is placed where it should be and that each is properly wired.
2. Clear the table or bench where you work and arrange your tools for easy use.
3. See that your soldering iron is clean and ready for use.
4. Examine Fig. 7-1 and 7-2 to see the assembling and wiring to be done in this part of the lesson.

JOB 7-1

To mount meter movement, as shown in Fig. 7-3.

Procedure.

Step 1. Place the four brass meter-mounting screws through the four holes in the panel and the meter through the large

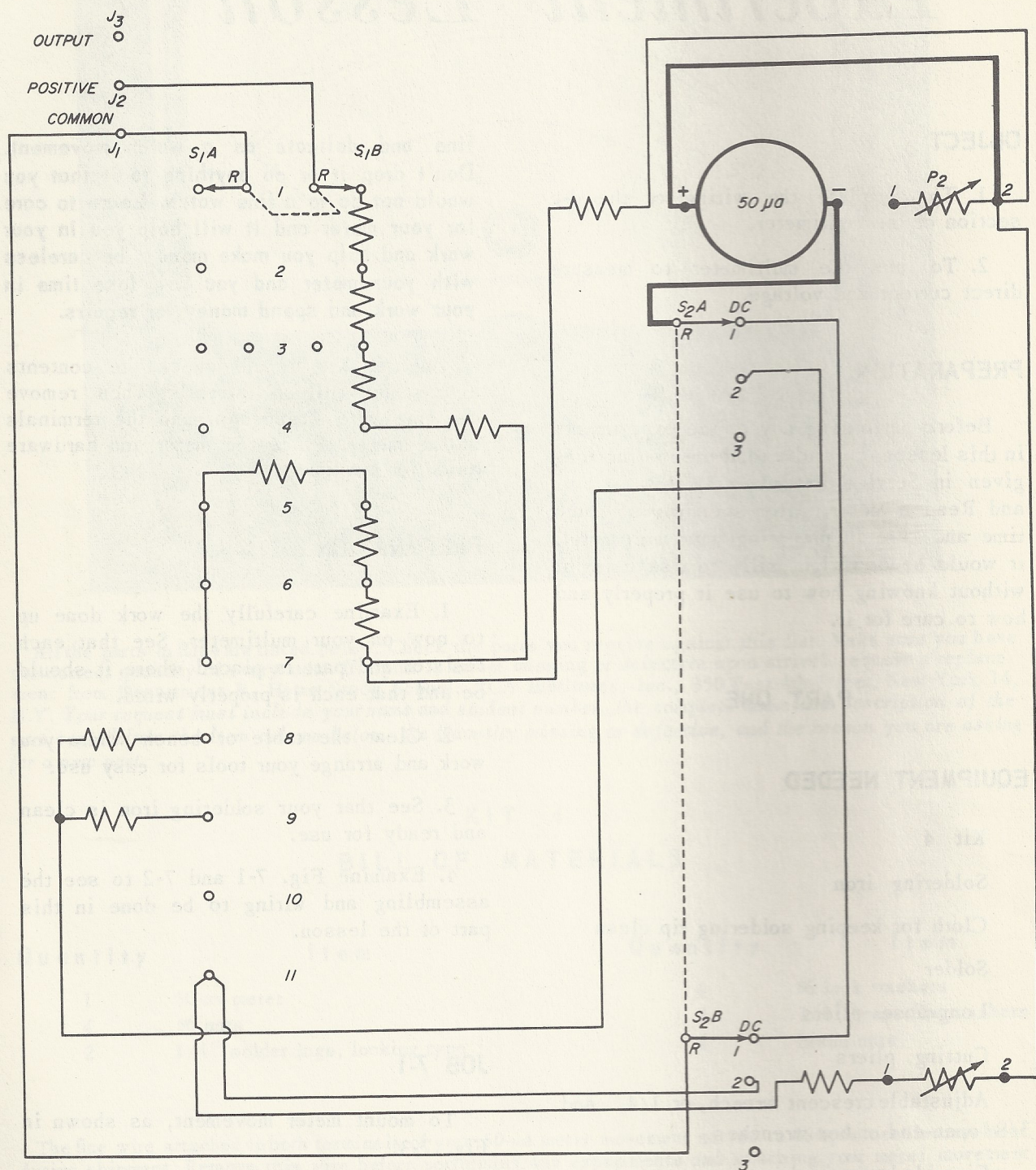


Fig. 7-1 Meter Connections to be Made in This Lesson

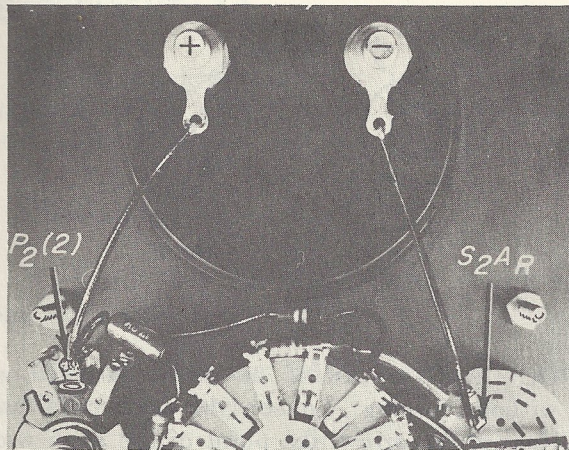


Fig. 7-2

center hole so that the top of the meter faces the top of the panel.

Step 2. Fasten the meter in place by tightening with one small lockwasher and one 6-32 nut on each meter screw.

Caution: Be very careful in tightening the meter nuts. If you use too much force, you may crack the bakelite case of the meter movement or loosen the screws from the meter.

Step 3. Make sure that the large meter lugs are clean; then mount them on the meter terminal screws. Place each lug with the tabs facing in the direction shown in Fig. 7-4a. Place a brass washer and a large meter nut on top of each lug.

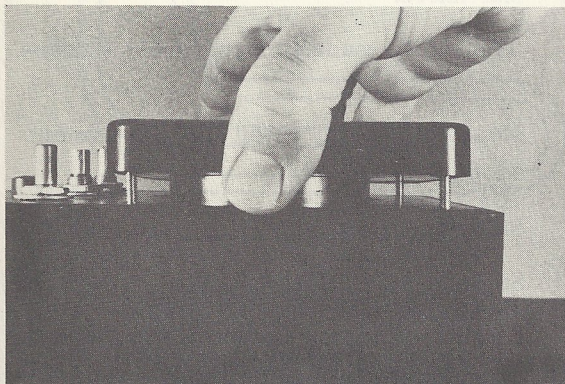
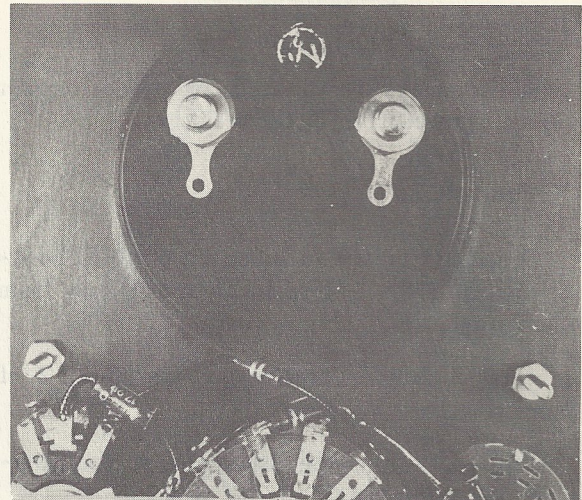
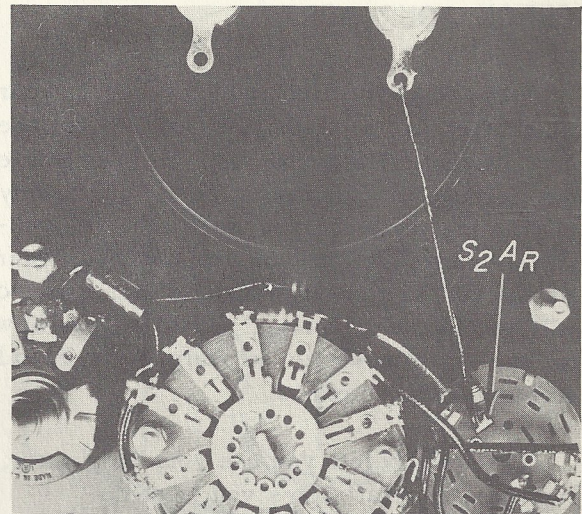


Fig. 7-3



(a)



(b)

Fig. 7-4

JOB 7-2

To connect the rotor of switch S_2A to the negative meter terminal.

Procedure.

Step 1. Cut a 3-inch length of solid hook-up wire. Strip 1/4 inch of insulation from each end.

Step 2. Solder one end to S_2AR .

Step 3. Dress the wire neatly, as shown in Fig. 7-4b, and solder the other end to the negative meter terminal.

JOB 7-3

To connect terminal 2 of potentiometer P_2 to the positive meter terminal.

Procedure.

Step 1. Cut a 3-inch length of solid hook-up wire. Strip $1/4$ inch of insulation from each end.

Step 2. Solder one end to terminal 2 of potentiometer P_2 .

Step 3. Solder the other end to the positive meter terminal.

CHECK YOUR WORK

With the connection made in Step 3, your multimeter is wired to measure d-c voltage and current. Later on you will complete the ohmmeter sections. When you study alternating current, you will receive additional parts, which you will add to your multimeter so that it will also measure a-c voltage. In the meantime, you will learn how to use your meter to measure voltage and currents in d-c circuits.

However, before you use your multimeter, there are several things you must do.

1. Check your wiring and placement of parts.
2. See that all the connections you have made are soldered (except S_2A_2).
3. Examine the RANGE switch, S_1 , for bits of wire or solder that may have dropped down between the contacts.
4. When you are sure that everything is in its proper place, turn the meter panel right side up and insert the meter in the case. Fasten the meter panel at the four corners with the four small panel screws. Tighten the screws carefully so that you do not cause too much strain on the panel corners.

ADJUST KNOBS

Turn the FUNCTION switch (AC-OHMS-

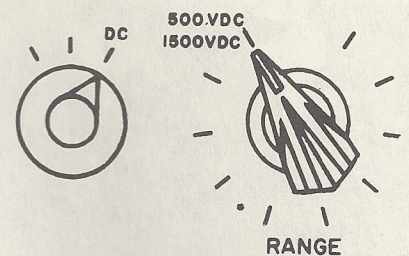


Fig. 7-5

DC) knob clockwise as far as it will go without forcing. Loosen the set screw and line up the arrow-like point of the knob with the DC marker line, as shown in Fig. 7-5. Retighten the set screw.

Turn the RANGE switch clockwise as far as it will go without forcing. Loosen the set screw and line up the pointer knob with the 500-VDC marker line. Retighten the set screw. The knob should now indicate each range position correctly. To check this, turn the knob counterclockwise as far as it will go. It should come to rest on the $R \times 10K$ position. Turn the knob to the 500 VDC position and leave it there.

Caution: Before attempting to use your multimeter, be sure to read carefully the instructions given in Service Practices 7, *How To Read Meters*.

PART TWO**EQUIPMENT NEEDED**

Multimeter

Test prods made in Experiment Lesson 2

Resistor board wired in Experiment Lesson 1

Soldering iron

Solder

Cloth for keeping soldering tip clean

Long-nose pliers

Three 1.5-volt cells from Kit 3

Two alligator clips from Kit 1

EXPERIMENT 7-1

To test the multimeter for a voltage reading on the 5 VDC scale with a 1.5-volt dry cell.

Procedure.

Step 1. Turn the FUNCTION switch to the DC marker line.

Step 2. Turn the RANGE switch to the 5 VDC marker line.

Step 3. Place the phone tip of the black test lead in the black COMMON pin jack and the tip of the red test lead in the red(+, meaning positive) pin jack. If you have performed these three steps correctly, your multimeter and test leads will look like the meter shown in Fig. 7-6.

Step 4. Press the point of the black test prod firmly against the negative zinc electrode of one of the 1.5-volt dry cells. Press the point of the red test prod against the positive brass electrode of the dry cell, as shown in Fig. 7-7a. The meter needle should be in about the position shown in Fig. 7-7b.

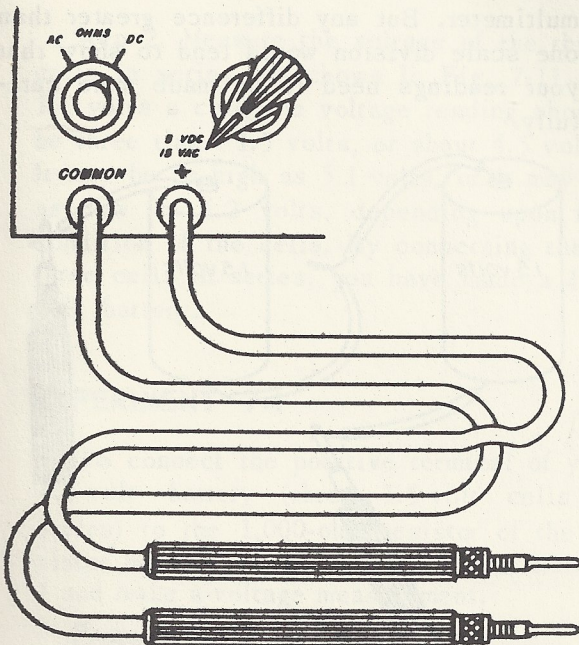


Fig. 7-6

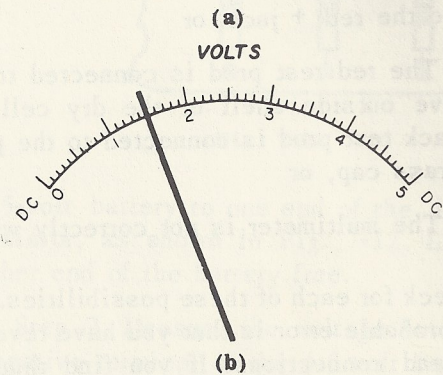
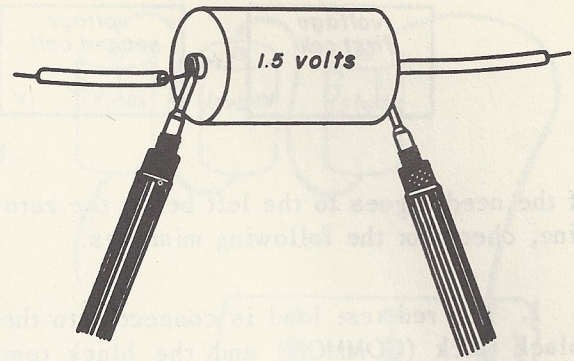


Fig. 7-7

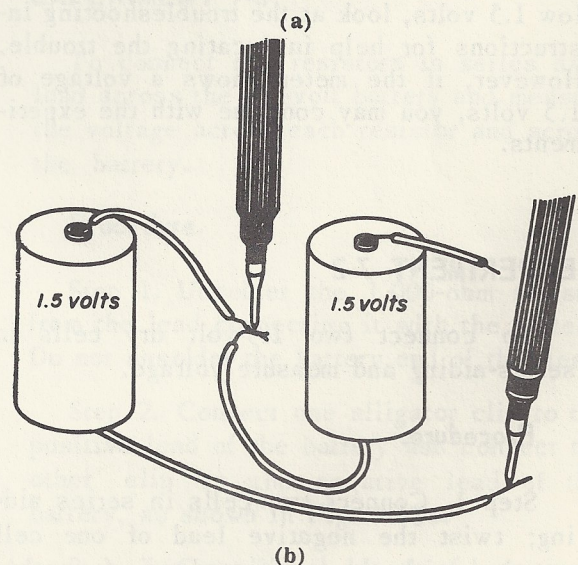
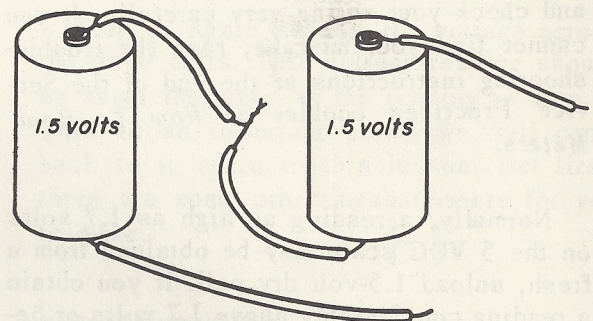


Fig. 7-8

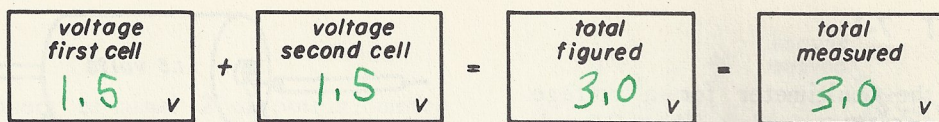


Fig. 7-9

If the needle goes to the left below the zero line, check for the following mistakes:

1. The red test lead is connected to the black jack (COMMON) and the black test lead to the red + jack, or
2. The red test prod is connected to the negative outside shell of the dry cell and the black test prod is connected to the positive brass cap, or
3. The multimeter is not correctly wired.

Check for each of these possibilities. The most probable error is that you have reversed test lead connections. If you find that you haven't made one of the first two errors, remove the meter assembly from the meter box and check your wiring very carefully. If you cannot find your mistake, read the troubleshooting instructions at the end of the Service Practices booklet on *How To Read Meters*.

Normally, a reading as high as 1.7 volts on the 5 VDC scale may be obtained from a fresh, unloads 1.5-volt dry cell. If you obtain a reading considerably above 1.7 volts or below 1.5 volts, look at the troubleshooting instructions for help in locating the trouble. However, if the meter shows a voltage of 1.5 volts, you may continue with the experiments.

EXPERIMENT 7-2

To connect two 1.5-volt dry cells in series-aiding and measure voltage.

Procedure.

Step 1. Connect two cells in series aiding; twist the negative lead of one cell together with the positive lead of another cell, as shown in Fig. 7-8a.

Step 2. Measure the voltage of the first cell, as shown in Fig. 7-8b. It should be about 1.5-volts. Read the meter carefully and record your reading in the first box of Fig. 7-9.

Step 3. Measure the voltage of the second cell. Read this voltage carefully and record it in the second box of Fig. 7-9.

Step 4. Add these two readings and write the total in the third box of Fig. 7-9.

Step 5. Measure the voltage of the two cells in series as shown in Fig. 7-10. Read the meter carefully and record this voltage in the fourth box of Fig. 7-9. By connecting these two cells in series aiding, you have made a 3-volt battery.

If you have read the meter carefully and added accurately, the voltage in the third box should equal the voltage reading in the fourth box. Of course, the reading may vary as much as one scale division and still be within the accuracy rating of the assembled multimeter. But any difference greater than one scale division would tend to show that your readings need to be made more carefully.

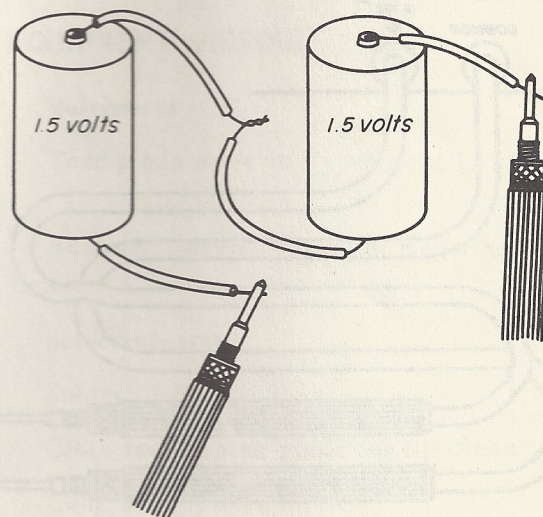


Fig. 7-10

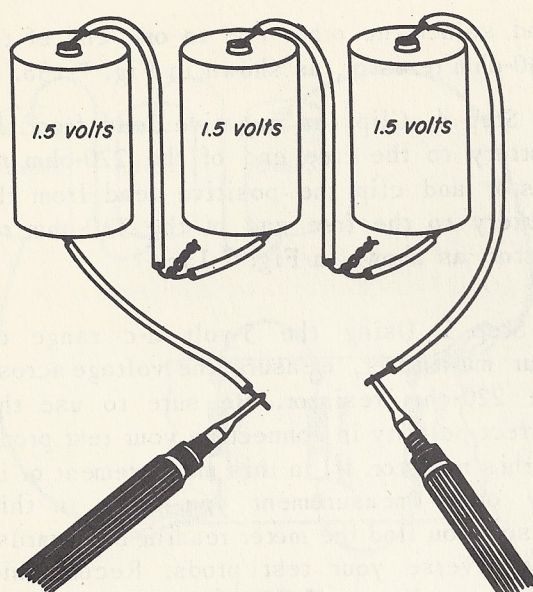


Fig. 7-11

EXPERIMENT 7-3

To connect three 1.5-volt dry cells in series aiding and make a voltage measurement.

Procedure.

Step 1. Connect the remaining 1.5-volt cell in series aiding with the two cells already connected together, as shown in Fig. 7-11.

Step 2. Measure the voltage of the three cells in series, as shown in Fig. 7-11. At 1.5 volts a cell, the voltage reading should be three times 1.5 volts, or about 4.5 volts. It may be as high as 5.1 volts, or it may be as low as 4.2 volts, depending upon the condition of the cells. By connecting these three cells in series, you have made a 4.5-volt battery.

EXPERIMENT 7-4

To connect the positive terminal of your 4.5-volt battery (three 1.5-volt cells in series) to the 1,000-ohm resistor of the resistor board you made in Experiment Lesson 1 and make a voltage measurement.

Procedure.

Step 1. Solder the positive lead of the

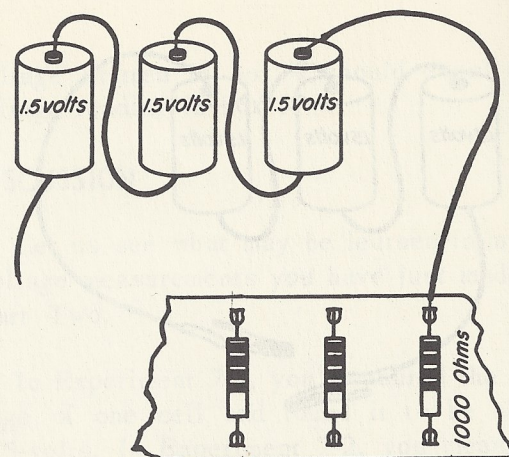


Fig. 7-12

4.5-volt battery to one end of the 1,000-ohm resistor, as shown in Fig. 7-12. Leave the other end of the battery free.

Step 2. Measure the voltage between the negative terminal of the 4.5-volt battery and the free end of the thousand-ohm resistor. Record the voltage here 4.55

Step 3. Again measure the voltage across the three cells. This voltage reading should be about the same as the reading in Step 2. This is an important point. We will come back to it again in this lesson. But first, there are some other measurements for you to make. 4.6

EXPERIMENT 7-5

To connect two resistors in series as a load across the 4.5-volt battery and measure the voltage across each resistor and across the battery.

Procedure.

Step 1. Unsolder the 1,000-ohm resistor from the lead connecting it with the battery. Do not unsolder the battery end of this lead.

Step 2. Connect one alligator clip to the positive lead of the battery and connect the other clip to the negative lead of the battery, as shown in Fig. 7-13a.

Step 3. Cut a 2-inch length of bare tinned wire. Solder one end to the 220-ohm resistor

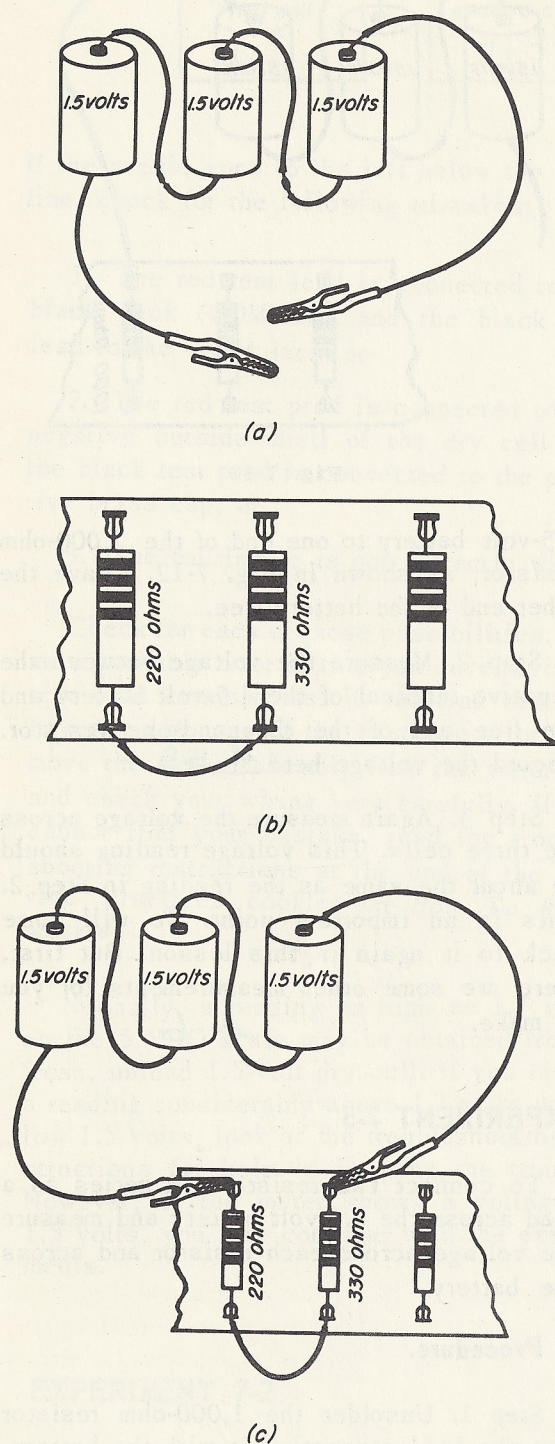


Fig. 7-13

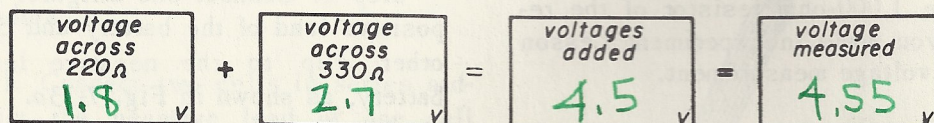


Fig. 7-14

and solder the other end to one end of the 330-ohm resistor, as shown in Fig. 7-13b.

Step 4. Clip the negative lead from the battery to the free end of the 220-ohm resistor and clip the positive lead from the battery to the free end of the 330-ohm resistor, as shown in Fig. 7-13c.

Step 5. Using the 5-volt d-c range on your multimeter, measure the voltage across the 220-ohm resistor. Be sure to use the correct polarity in connecting your test prods to this resistor. If, in this measurement or in any other measurement you make in this lesson, you find the meter reading backwards, just reverse your test prods. Record this voltage reading in the first box of Fig. 7-14.

Step 6. Measure the voltage across the 330-ohm resistor. Record this voltage in the second box of Fig. 7-14.

Step 7. Add the two voltage readings and record the amount in the third box of Fig. 7-14.

Step 8. Measure the voltage at the positive and negative terminals of the battery. Record this reading in the fourth box of Fig. 7-14. Disconnect the battery from the resistors. You do this so as not to waste battery energy. If your measurements are correct, the voltage shown in box 3 should equal the voltage shown in box 4.

EXPERIMENT 7-6

To connect three resistors in series and place them as a load across the 4.5-volt battery, and to measure the voltages.

Procedure.

Step 1. Cut a 2-inch length of bare tinned wire. Solder one end to the free end

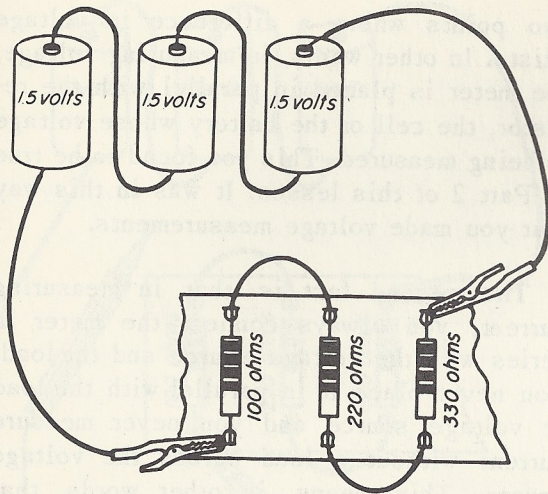


Fig. 7-15

of the 220-ohm resistor. Solder the other end of the wire to one end of the 100-ohm resistor.

Step 2. Clip the negative lead of the 4.5-volt battery to the free end of the 100-ohm resistor. Clip the positive terminal to the free end of the 330-ohm resistor, as shown in Fig. 7-15.

Step 3. Measure the voltage across the 100-ohm resistor. Record this reading in the first box of Fig. 7-16.

Step 4. Measure the voltage across the 220-ohm resistor and record it in the second box of Fig. 7-16.

Step 5. Measure the voltage across the 330-ohm resistor and record it in the third box.

Step 6. Add the three voltages readings and write the amount in the fourth box.

Step 7. Measure the voltage across the terminals of the battery and record the amount in the fifth box. Disconnect the battery from the circuit by unclipping the battery leads from the resistor board. The

voltage written in box 4 should equal the voltage reading in box 5.

DISCUSSION

Let us see what may be learned from the voltage measurements you have just made in Part Two.

In Experiment 7-1, you measured the voltage of one cell and found it to be about 1.5-volts. In Experiment 7-2, you measured the voltage of two cells in series and you found this voltage to be about 3 volts. In Experiment 7-3, you measured the voltage of three cells in series and you found it to be about 4.5-volts. From your own measurements, therefore, you found that the theory you studied in Theory Lesson 5 is true; the voltage of one cell adds to the voltage of another cell when they are connected in series aiding – that is, when the positive terminal of one cell is connected to the negative terminal of the next cell.

We will skip Experiment 7-4 for a moment, and go on to Experiment 7-5, in which you placed two resistors in series as a load across the battery and found that the applied voltage (from the battery) divided into two parts. The greater voltage was across the resistor with the greater resistance. You found that the sum of the voltage drops across the resistors was equal to the applied voltage. In Experiment 7-6, when you connected three resistors in series, you found that the applied voltage divided into three parts, that the smallest voltage drop was across the resistor with the least resistance, and that the greatest voltage drop was across the resistor with the most resistance. Again, you found that the sum of the voltage drops was equal to the applied voltage. This important fact is discussed completely in Theory Lesson 8.

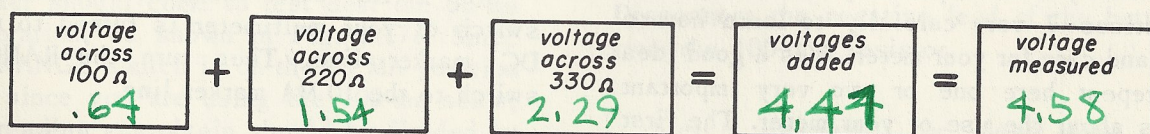


Fig. 7-16

Now, let us examine what you found in Experiment 7-4. You found that there was no voltage drop across the 1,000-ohm resistor. Yet, in later steps, you found noticeable voltage drops across even resistors of much less resistance. It seems puzzling at first, but the reason is not hard to understand. You could measure no voltage drop across the 1,000-ohm resistor because you were measuring voltage in an open circuit. It was an open circuit because only one terminal of the battery was connected to the resistor. The other terminal of the battery and the other end of the resistor were free. When a circuit is open, there is no current flow. According to Ohm's Law, which you studied in Lesson 5, *voltage is equal to current times resistance* ($E = IR$). If there is no current, there can be no voltage drop. If the circuit has been completed (if the free end of the 1000-ohm resistor has been connected to the other terminal of the battery) there would have been a voltage drop across the resistor.

Actually, when the meter was connected to the free end of the resistor and the free end of the battery, the circuit was completed by the meter; but the amount of current flowing through the meter was so small that there was practically no difference between the readings at either end of the resistor. For that reason, we can ignore this meter current. The fact that there is no voltage drop across the resistor in an open circuit is one of the tests that a serviceman uses in locating open circuits in a radio receiver. For that reason, it is discussed here.

PART THREE

INFORMATION

While you have probably studied Service Practices 7 very carefully to learn how to use and care for your meter, it is a good idea to repeat here one or two very important facts about the use of your meter. The first of these is that voltage is measured by placing the test prods of the meter at any

two points where a difference in voltage exists. In other words, in measuring voltage, the meter is placed in parallel with the resistor, the cell or the battery whose voltage is being measured. This you found to be true in Part 2 of this lesson. It was in this way that you made voltage measurements.

The second fact is that in measuring current, you always connect the meter in series with the voltage source and the load. You never place it in parallel with the load or voltage source and you never measure current without a load across the voltage source. This means, in other words, that you never try to measure current by placing an ammeter or milliammeter across a battery, a cell, or any other source of electrical power. Nothing that you may ever be told about the use of a meter can be more important than this. There is no easier way to burn out a meter movement than to be careless when measuring current.

EQUIPMENT NEEDED

The same equipment used in Part Two

EXPERIMENT 7-7

To measure the current flowing in the circuit wired in Experiment 7-6 of Part 2. This circuit consists of three resistors and a battery. Current is measured at several points in the circuit.

Procedure.

Step 1. The 100-ohm resistor, the 220-ohm resistor, and the 330-ohm resistor should still be connected in series from the last experiment. Clip the positive lead from the battery to the free end of the 330-ohm resistor.

Step 2. Be sure that the FUNCTION switch of your multimeter is turned to the DC marker line. Then turn the RANGE switch to the 10 MA marker line.

Step 3. Place the positive (red) test prod firmly against the free end of the 100-

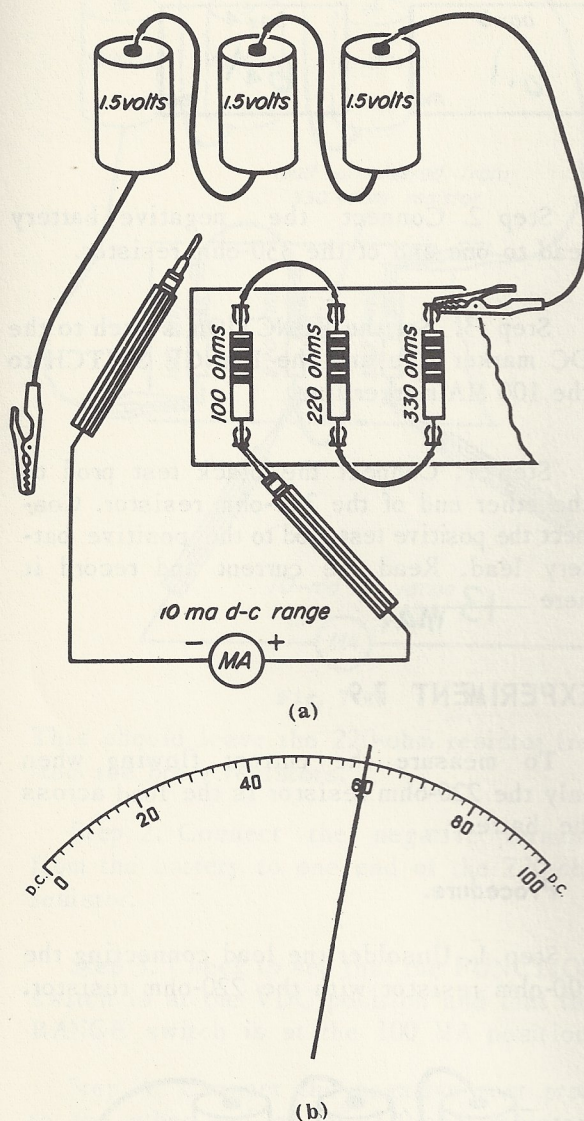


Fig. 7-17

ohm resistor, as shown in Fig. 7-17a. Then, as you watch the meter needle, make a rapid brushing stroke with the point of the negative (black) test prod across the lead from the negative terminal of the battery. This brushing stroke is made so that you make and break connection with the battery in one stroke. If, while you make this momentary connection, the meter moves rapidly to the right of the scale, remove both test prods from the circuit. Normally, the meter pointer should come to rest near the 60-ma calibration, as shown in Fig. 7-17b. Since the RANGE switch is on the 10 MA position and since you are using the 100-ma scale, the reading you obtain should be divided by 10. Thus, a current of approximately 6 ma is flowing through the circuit.

If you obtain a reading that is not near 6 ma, a mistake may have been made in the connections of the circuit or a mistake has been made in wiring the current ranges of the meter. If the circuit connections are exactly as shown in Fig. 7-17a, then remove the meter assembly from the meter box and check the wiring and placement of resistors in Experiment Lesson 5. If you can find no error, turn to the troubleshooting instructions in Service Practices 8 for help in locating the trouble.

If the meter falls below zero when you make the first brushing stroke with your test prod, you will find that either the battery is connected with the wrong polarity or the test prods are not connected correctly. When you have located the trouble, connect the positive test prod to the free end of the 100-ohm resistor and, with the negative test prod, lightly brush the negative battery lead as before.

If the meter rises slowly, as it should, make a firm connection with the negative lead from the battery so that you may make a careful reading. Record this current reading in the first box of Fig. 7-18.

Step 4. Open the circuit between the 100-ohm and 220-ohm resistors by unsoldering one end of the wire that connects them. Clip the negative lead from the battery to the free end of the 100-ohm resistor. The positive clip from the battery should already be connected to the free end of the 330-ohm resistor. As shown in Fig. 7-19, the circuit is now open between the 100-ohm and 220-ohm resistors.

Step 5. Connect the positive test prod to the free end of the 220-ohm resistor and the negative test prod to the free end of the 100-ohm resistor. Read the current and record it in the second box of Fig. 7-18. Disconnect the negative lead of the battery from the 100-ohm resistor.

Step 6. Resolder the lead from the 220-ohm resistor to the free end of the 100-ohm resistor. Unsolder one end of the

that, in each case, the meter is in series with the voltage source and the load resistors. All of these readings were the same. So, in this experiment, you verified a law that is discussed completely in Theory Lesson 8. This law states:

In a series circuit, the same current flows in each part of the circuit.

In Experiment 7-7, you connected the 100-ohm, 220-ohm, and 330-ohm resistors in series with meter that has a resistance of 100 ohms on the 10 MA RANGE. The total resistance of the circuit is thus 750 ohms. The total voltage is approximately 4.5 volts. Using Ohm's Law, the calculated value of current is 6 ma. Look back at your results to see if you obtained approximately 6 ma.

In Experiment 7-8, you connected a 330-ohm resistor in series with the resistance of the meter, which at the 100 MA RANGE is 10 ohms. The total resistance is thus 340 ohms. The voltage of the source is 4.5 volts. The calculated value of current is approximately 13.2 ma.

In Experiment 7-9, the 220-ohm resistor was connected in series with the resistance of the meter (10 ohms), and the series combination connected across approximately 4.5 volts. The calculated current is about 19.5 ma.

In general, you see, with the same applied voltage, the greater the load resistance is, the lower the current; and the lower the load resistance, the higher is the current.

1.5V Battery -

Open Circuit Voltage - 1.4 V

Closed Circuit (Dead short) Voltage - .15 V

* " " 100 Ω load — 1.4 V

1000 Ω load — 1.4 V

100,000 Ω load — 1.4 V